

IN THE CLAIMS

Please amend the claims as follows, substituting any amended claim(s) for the corresponding pending claim(s):

1 1. (Original) A radio frequency integrated circuit (RFIC) comprises:
2 transmitter section operably coupled to convert outbound baseband signals into outbound radio
3 frequency (RF) signals;
4 receiver section operably coupled to convert inbound RF signals into inbound baseband signals,
5 wherein the receiver section includes: a low noise amplifier operably coupled to amplify the inbound RF
6 signals to produce amplified inbound RF signals;
7 down-conversion module operably coupled to convert the amplified inbound RF signals into
8 baseband in-phase components and quadrature components;
9 orthogonal-normalizing module operably coupled to:
10 obtain a first coefficient that is based on at least one of power of the baseband in-phase
11 components, power of the baseband quadrature components, and cross-correlation between the
12 baseband in-phase components and the baseband quadrature components;
13 obtain a second coefficient that is based on at least one of the power of the baseband in-
14 phase components, the power of the baseband quadrature components, and the cross-correlation
15 between the baseband in-phase components and the baseband quadrature components;
16 normalize an orthogonal relationship between the baseband in-phase components and the
17 baseband quadrature components based on the first coefficient and the second coefficient to
18 produce normalized in-phase components and normalized quadrature components; and
19 baseband processor operably coupled to recapture data from the normalized in-phase and
20 quadrature components.

1 2. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module comprises:
2 a first multiplier module operably coupled to multiple the baseband in-phase components with the
3 first coefficient to produce the normalized in-phase components;
4 a second multiplier module operably coupled to multiple the baseband in-phase components with
5 the second coefficient to produce the cross-correlation; and
6 a subtraction module operably coupled to subtract the cross-correlation from the baseband
7 quadrature components to produce the normalized quadrature components.

1 3. (Original) The RFIC of claim 2, wherein the first multiplier module comprises:
2 a first plurality of shift registers operably coupled to produce a plurality of shifted representations
3 of the baseband in-phase components;
4 switch matrix operably coupled to pass selected ones of the plurality of shifted representations of
5 the baseband in-phase components and the baseband in-phase components based on the first coefficient;
6 and
7 an adder operably coupled to add the selected ones of the plurality of shifted representations of
8 the baseband in-phase components and the baseband in-phase components to produce the normalized in-
9 phase components.

1 4. (Original) The RFIC of claim 2, wherein the second multiplier module comprises:
2 a first plurality of shift registers operably coupled to produce a plurality of shifted representations
3 of the baseband in-phase components;
4 switch matrix operably coupled to pass selected ones of the plurality of shifted representations of
5 the baseband in-phase components based on the second coefficient; and
6 an adder operably coupled to add the selected ones of the plurality of shifted representations of
7 the baseband in-phase components to produce the cross-correlation.

1 5. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module comprises:
2 a first multiplier module operably coupled to multiply the baseband in-phase components with the
3 second coefficient to produce the cross-correlation;
4 a subtraction module operably coupled to subtract the cross-correlation from the baseband
5 quadrature components to produce phase adjusted quadrature components; and
6 a second multiplier module operably coupled to multiply the phase adjusted quadrature
7 components with the first coefficient to produce the normalized quadrature components, wherein the
8 baseband in-phase components are passed as the normalized in-phase components.

1 6. (Currently Amended) The RFIC of claim 1, wherein the orthogonal-normalizing module
2 comprises:
3 a first programmable register for storing the first coefficient; and
4 a second programmable register for storing the second coefficient, wherein the first and second
5 coefficients are determined by a ~~trial and error manufacturing test~~ trial and error manufacturing test.

1 7. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module comprises:
2 a full matrix multiply module operably coupled to multiply the baseband in-phase components
3 and the baseband quadrature components with a coefficient matrix that includes the first and second
4 coefficients to produce the normalized in-phase components and the normalized quadrature components.

1 8. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module further functions to:
2 measure local oscillation leakage power to produce a first power measurement;
3 provide a first magnitude signal to an in-phase portion of the receiver section and a zero
4 magnitude signal to a quadrature portion of the receiver section;
5 measure power of the in-phase portion and power of the quadrature portion while processing the
6 first magnitude signal and the zero magnitude signal, respectively, to produce a second power
7 measurement;
8 provide the first magnitude signal to the quadrature portion of the receiver section and the zero
9 magnitude signal to the in-phase portion of the receiver section;
10 measure the power of the in-phase portion and the power of the quadrature portion while
11 processing the zero magnitude signal and the first magnitude signal, respectively, to produce a third
12 power measurement;
13 determine a gain imbalance based on the first, second, and third power measurements;
14 provide a second magnitude signal to the in-phase portion and to the quadrature portion;
15 measure the power of the in-phase and quadrature portions while processing the second
16 magnitude signal to produce a fourth power measurement;
17 provide the second magnitude signal to the in-phase portion and a negative second magnitude
18 signal to the quadrature portion;
19 measure the power of the in-phase portion and the power of the quadrature portion while
20 processing the second magnitude signal and the negative second magnitude signal, respectively, to
21 produce a fifth power measurement; and
22 determine a phase imbalance based on the first, fourth, and fifth power measurements, wherein
23 the gain imbalance and the phase imbalance correspond to the power of the baseband in-phase
24 components, the power of the baseband quadrature components, and the cross-correlation between the
25 baseband in-phase components and the baseband quadrature components to determine the first and second
26 coefficients.

1 9. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module further functions to
2 obtain the first and second coefficients by:

3 measuring in-phase signal level of the receiver section while processing a sine wave;
4 measuring quadrature signal level of the receiver section while processing the sine wave;
5 determining the power of the baseband in-phase components based on the in-phase signal level;
6 determining the power of the baseband quadrature components based on the quadrature signal
7 level;
8 determining cross-correlation power based on the in-phase signal level and the quadrature signal
9 level; and
10 determining the first and second coefficients based on the power of the baseband in-phase
11 components, the of the baseband quadrature components, and the cross-correlation power.

1 10. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module normalizes the
2 orthogonal relationship between the baseband in-phase components and the baseband quadrature
3 components by:

4 selecting one of the baseband in-phase components and the baseband quadrature components as a
5 reference component; and
6 normalizing another one of the baseband in-phase components and the baseband quadrature
7 components to the reference component.

1 11. (Original) The RFIC of claim 1, wherein the orthogonal-normalizing module further functions to:
2 update the first and second coefficients to compensate for at least one of temperature variation and aging.

1 12. (Original) A radio frequency integrated circuit (RFIC) comprises:
2 transmitter section operably coupled to convert outbound baseband signals into outbound radio
3 frequency (RF) signals;
4 receiver section operably coupled to convert inbound RF signals into inbound data, wherein the
5 receiver section includes: a low noise amplifier operably coupled to amplify the inbound RF signals to
6 produce amplified inbound RF signals;
7 down-conversion module operably coupled to convert the amplified inbound RF signals into
8 baseband in-phase components and quadrature components;
9 orthogonal-normalizing module including:
10 an in-phase power module operably coupled to determine power of the baseband in-phase
11 components;
12 a quadrature power module operably coupled to determine power of the quadrature
13 components;
14 a cross-correlation power module operably coupled to determine a cross-correlation
15 power based on the baseband in-phase and quadrature components; and
16 normalizing module operably coupled to normalize the baseband in-phase components
17 and the baseband quadrature components based on the power of the baseband in-phase
18 components, the power of the baseband quadrature components, and the cross-correlation power
19 to produce normalized in-phase components and normalized quadrature components; and
20 baseband processor operably coupled to recapture the inbound data from the normalized in-phase
21 and quadrature components.

1 13. (Original) The RFIC of claim 12, wherein the normalizing module comprises:
2 a coefficient module operably coupled to determine coefficients based on the power of the
3 baseband in-phase components, the power of the baseband quadrature components, and the cross-
4 correlation power, wherein the baseband in-phase components and the baseband quadrature components
5 are normalized based on the coefficients.

1 14. (Original) The RFIC of claim 12, wherein the in-phase power module comprises:
2 a multiplier operably coupled to square the baseband in-phase components to produce squared in-
3 phase values; and
4 an accumulator operably coupled to accumulate the squared in-phase values for a predetermined
5 period of time to produce the power of the baseband in-phase components.

1 15. (Original) The RFIC of claim 12, wherein the quadrature power module comprises:
2 a multiplier operably coupled to square the baseband quadrature components to produce squared
3 quadrature values; and
4 an accumulator operably coupled to accumulate the squared quadrature values for a
5 predetermined period of time to produce the power of the baseband quadrature components.

1 16. (Original) The RFIC of claim 12, wherein the cross-correlation power module comprises:
2 a multiplier operably coupled to multiply the baseband in-phase components and the baseband
3 quadrature components to produce cross-correlation values; and
4 an accumulator operably coupled to accumulate the cross-correlation values for a predetermined
5 period of time to produce the cross-correlation power.

1 17. (Original) A radio frequency integrated circuit (RFIC) comprises:
2 receiver section operably coupled to convert inbound radio frequency (RF) signals into inbound
3 baseband signals;
4 transmitter section operably coupled to convert outbound data into outbound RF signals, wherein
5 the transmitter section includes:
6 baseband processor operably coupled to convert the outbound data into the baseband in-
7 phase components and baseband quadrature components;
8 orthogonal-normalizing module operably coupled to:
9 obtain a first coefficient that is based on at least one of a gain imbalance and
10 phase imbalance;
11 obtain a second coefficient that is based on at least one of the gain imbalance and
12 the phase imbalance;
13 normalize an orthogonal relationship between the baseband in-phase components
14 and the baseband quadrature components based on the first coefficient and the second
15 coefficient to produce normalized in-phase components and normalized quadrature
16 components;
17 up-conversion module operably coupled to convert the normalized in-phase components and
18 normalized quadrature components into RF signals; and
19 power amplifier operably coupled to amplify the RF signals to produce the outbound RF signals.

1 18. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module comprises:
2 a first multiplier module operably coupled to multiple the baseband in-phase components with the
3 first coefficient to produce the normalized in-phase components;
4 a second multiplier module operably coupled to multiple the baseband in-phase components with
5 the second coefficient to produce cross coupled in-phase components; and
6 a subtraction module operably coupled to subtract the cross coupled in-phase components from
7 the baseband quadrature components to produce the normalized quadrature components.

1 19. (Original) The RFIC of claim 18, wherein the first multiplier module comprises:
2 a first plurality of shift registers operably coupled to produce a plurality of shifted representations
3 of the baseband in-phase components;
4 switch matrix operably coupled to pass selected ones of the plurality of shifted representations of
5 the baseband in-phase components and the baseband in-phase components based on the first coefficient;
6 and
7 an adder operably coupled to add the selected ones of the plurality of shifted representations of
8 the baseband in-phase components and the baseband in-phase components to produce the normalized in-
9 phase components.

1 20. (Original) The RFIC of claim 18, wherein the second multiplier module comprises:
2 a first plurality of shift registers operably coupled to produce a plurality of shifted representations
3 of the baseband in-phase components;
4 switch matrix operably coupled to pass selected ones of the plurality of shifted representations of
5 the baseband in-phase components based on the second coefficient; and
6 an adder operably coupled to add the selected ones of the plurality of shifted representations of
7 the baseband in-phase components to produce the cross coupled in-phase components.

1 21. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module comprises:
2 a first multiplier module operably coupled to multiply the baseband in-phase components with the
3 second coefficient to produce cross coupled in-phase components;
4 a subtraction module operably coupled to subtract the cross coupled in-phase components from
5 the baseband quadrature components to produce phase adjusted quadrature components; and
6 a second multiplier module operably coupled to multiply the phase adjusted quadrature
7 components with the first coefficient to produce the normalized quadrature components, wherein the
8 baseband in-phase components are passed as the normalized in-phase components.

- 1 22. (Currently Amended) The RFIC of claim 17, wherein the orthogonal-normalizing module
2 comprises:
3 a first programmable register for storing the first coefficient; and
4 a second programmable register for storing the second coefficient, wherein the first and second
5 coefficients are determined by a ~~trial-and-error~~ trial and error manufacturing test of the gain imbalance
6 and the phase imbalance.
- 1 23. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module comprises:
2 a full matrix multiply module operably coupled to multiply the baseband in-phase components
3 and the baseband quadrature components with a coefficient matrix that includes the first and second
4 coefficients to produce the normalized in-phase components and the normalized quadrature components.

1 24. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module further functions
2 to:
3 measure local oscillation leakage power to produce a first power measurement;
4 provide a first magnitude signal to an in-phase portion of the transmitter section and a zero
5 magnitude signal to a quadrature portion of the transmitter section;
6 measure power of the in-phase portion and power of the quadrature portion while processing the
7 first magnitude signal and the zero magnitude signal, respectively, to produce a second power
8 measurement;
9 provide the first magnitude signal to the quadrature portion of the transmitter section and the zero
10 magnitude signal to the in-phase portion of the transmitter section;
11 measure the power of the in-phase portion and the power of the quadrature portion while
12 processing the zero magnitude signal and the first magnitude signal, respectively, to produce a third
13 power measurement;
14 determine the gain imbalance based on the first, second, and third power measurements;
15 provide a second magnitude signal to the in-phase portion and to the quadrature portion;
16 measure the power of the in-phase and quadrature portions while processing the second
17 magnitude signal to produce a fourth power measurement;
18 provide the second magnitude signal to the in-phase portion and a negative second magnitude
19 signal to the quadrature portion;
20 measure the power of the in-phase portion and the power of the quadrature portion while
21 processing the second magnitude signal and the negative second magnitude signal, respectively, to
22 produce a fifth power measurement; and
23 determine the phase imbalance based on the first, fourth, and fifth power measurements.

1 25. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module normalizes the
2 orthogonal relationship between the baseband in-phase components and the baseband quadrature
3 components by:
4 selecting one of the baseband in-phase components and the baseband quadrature components as a
5 reference component; and
6 normalizing another one of the baseband in-phase components and the baseband quadrature
7 components to the reference component.

1 26. (Original) The RFIC of claim 17, wherein the orthogonal-normalizing module further functions
2 to:

3 update the first and second coefficients to compensate for at least one of temperature variation
4 and aging.

1 27. (Original) A method for orthogonal normalization of a radio frequency integrated circuit (RFIC),
2 the method comprises:

3 determining phase imbalance and gain imbalance of a transmitter section of the RFIC;
4 normalizing baseband in-phase components and baseband quadrature components of the
5 transmitter section based on the phase imbalance and the gain imbalance of the transmitter section;
6 coupling the transmitter section to a receiver section of the RFIC in a loop back configuration;
7 providing a test signal from the transmitter section to the receiver section;
8 determining power of baseband in-phase components, power of baseband quadrature components,
9 and cross-correlation between the baseband in-phase components and the baseband quadrature
10 components of the receiver section while processing the test signal; and

11 normalizing the baseband in-phase components and the baseband quadrature components of the
12 receiver section based on the power of the baseband in-phase components, the power of the baseband
13 quadrature components, and the cross-correlation between the baseband in-phase components and the
14 baseband quadrature components.

1 28. (Original) The method of claim 27, wherein the normalizing the baseband in-phase components
2 of the receiver section comprises:

3 multiplying the baseband in-phase components with the first coefficient to produce the
4 normalized in-phase components;

5 multiplying the baseband in-phase components with the second coefficient to produce the cross-
6 correlation; and

7 subtracting the cross-correlation from the baseband quadrature components to produce the
8 normalized quadrature components.

1 29. (Original) The method of claim 27, wherein the determining phase imbalance and gain imbalance
2 of a transmitter section comprises:

3 measuring local oscillation leakage power to produce a first power measurement;
4 providing a first magnitude signal to an in-phase portion of the transmitter section and a zero
5 magnitude signal to a quadrature portion of the transmitter section;

6 measuring power of the in-phase portion and power of the quadrature portion while processing
7 the first magnitude signal and the zero magnitude signal, respectively, to produce a second power
8 measurement;

9 providing the first magnitude signal to the quadrature portion of the transmitter section and the
10 zero magnitude signal to the in-phase portion of the transmitter section;

11 measuring the power of the in-phase portion and the power of the quadrature portion while
12 processing the zero magnitude signal and the first magnitude signal, respectively, to produce a third
13 power measurement;

14 determining the gain imbalance based on the first, second, and third power measurements;

15 providing a second magnitude signal to the in-phase portion and to the quadrature portion;

16 measuring the power of the in-phase and quadrature portions while processing the second
17 magnitude signal to produce a fourth power measurement;

18 providing the second magnitude signal to the in-phase portion and a negative second magnitude
19 signal to the quadrature portion;

20 measuring the power of the in-phase portion and the power of the quadrature portion while
21 processing the second magnitude signal and the negative second magnitude signal, respectively, to
22 produce a fifth power measurement; and

23 determining the phase imbalance based on the first, fourth, and fifth power measurements.

1 30. (Original) The method of claim 27, wherein the determining the power of baseband in-phase
2 components, the power of baseband quadrature components, and the cross-correlation comprises:

3 measuring in-phase signal level of the receiver section while processing the test signal; measuring
4 quadrature signal level of the receiver section while processing the test signal;

5 determining the power of the baseband in-phase components based on the in-phase signal level;

6 determining the power of the baseband quadrature components based on the quadrature signal
7 level; and

8 determining cross-correlation power based on the in-phase signal level and the quadrature signal
9 level.

1 31. (Original) The method of claim 27 further comprises:
2 repeating the normalizing of the transmitter section and the receiver section to fine tune an
3 orthogonal relationship between the baseband in-phase components and baseband quadrature components
4 of the transmitter section and an orthogonal relationship between the baseband in-phase components and
5 baseband quadrature components of the receiver section.

1 32. (Original) The method of claim 27 further comprises, in an ordered sequence:
2 coupling the transmitter section to the receiver section in the loop back configuration;
3 providing the test signal from the transmitter section to the receiver section;
4 determining the power of baseband in-phase components, the power of baseband quadrature
5 components, and the cross-correlation between the baseband in-phase components and the baseband
6 quadrature components of the receiver section while processing the test signal;
7 normalizing the baseband in-phase components and the baseband quadrature components of the
8 receiver section based on the power of the baseband in-phase components, the power of the baseband
9 quadrature components, and the cross-correlation between the baseband in-phase components and the
10 baseband quadrature components;
11 determining the phase imbalance and the gain imbalance of the transmitter section;
12 normalizing baseband in-phase components and baseband quadrature components of the
13 transmitter section based on the phase imbalance and the gain imbalance of the transmitter section; and
14 repeating the ordered sequence of normalizing of the receiver section and the transmitter section
15 to fine tune an orthogonal relationship between the baseband in-phase components and baseband
16 quadrature components of the receiver section and an orthogonal relationship between the baseband in-
17 phase components and baseband quadrature components of the transmitter section.